

REVIEW ARTICLE

A Comprehensive analysis on Bioenergy Yield via Anaerobic Disintegration of Organic Matter

*P.M Diaz¹

¹Professor, Department of Mechanical Engineering, Sreyas institute of Engineering and Technology, Hyderabad, Telangana, India.

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ABSTRACT

Solid and liquid waste disposal by anaerobic digestion is feasible enough to produce biofuel by reducing volume of sludge. The rate of waste conversion to biogas in activated sludge process has been increasing as it reduces negative environmental effect and stabilizes ecological balance. A brief overview of substrates that is suitable for biogas yield has been presented, where it is clear that the feedstock with higher total solid concentration results to increase biofuel generation potential. It intends to provide various anaerobic disintegration techniques that emphasized on bioenergy development. Further, the recommendations over future scope have also been dealt with.

Keywords: Anaerobic digestion, Waste conversion, Biogas, Activated sludge process, Total solids.

1. INTRODUCTION

Bioenergy generated during biomethanation or solid state anaerobic digestion is the most productive choice for renewable source, where its digestate are utilized as natural fertilizer. Most of the waste from poultry/ dairy farms, crops, household wastes and algae/sewage sludge are dumped which becomes unsafe to the environment. On the other hand, treating all these give rise to energy efficient biofuel and fertilizer that is crucial for any country. Waste treatment is inexpensive but tedious. [1] Feedstock with solid concentration less than 15% is categorized to be liquid state, which normally includes food waste, sewage sludge and manures, whereas solid state takes into consideration of higher than 15%, where municipal solid waste and lignocellulosic organic substrates come into role. In case of solid state anaerobic digestion, it can be operated with lower reactor capacity and lesser energy is sufficient for heating. Again, its effluent becomes simple to handle as its moisture level is low. On contrary it requires huge quantity of inoculum and prolonged

retention period. Increasing in operating temperature enhances productivity of solid state anaerobic digestion. [2] Biomass substrate includes cellulose that is neither starch nor edible. Retrieval of biofuels from such feed stocks is common owing to the advanced techniques and minimum unit generation cost. The role of biofuel policies aids in developing energy sector where it influences the cost effectiveness and profitability of biogas generation. Fuels from green remains tend to generate fossil free energy, let recovering and minimize pollution. It is demonstrated that incorporation of co-substrates to manure produced higher yield than with the process where manure alone is used such that, both the biogas quantity and the digestate nutrient can be further improved. Several types of waste and manures are co-digested in improving the biogas quantity thereby optimizing in digestibility, reactor utilization and cost effectiveness. The co-digested remains are also found to enhance anaerobic disintegration. Hence the feedstock must be chosen in such a way that it prevents any adverse impacts including reduction of pH

*Corresponding author. Tel.: +919443558554

Email address: pauldiaz@sreyas.ac.in (P.M.Diaz)

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or accumulation of undesired by-products during defragmentation. High solid anaerobic disintegration is preferred since it eases the pretreatments and thus improves the stableness of the function in order to yield steady bioenergy. The schematic of the general experimental set up is shown in figure 1.

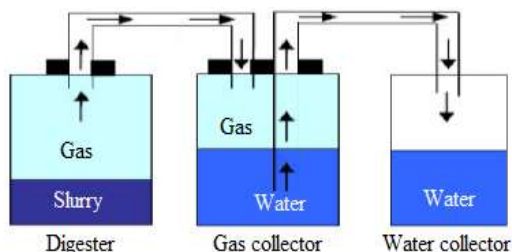


Figure 1. Bio gas production set up

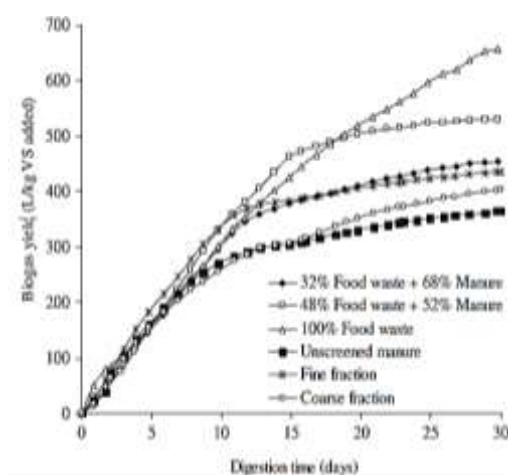
This article explains how such wastes can be treated to yield high biogas quantity. Researches confirm that rather than concentrating on a single substrate for biogas production mixing up of manures and wastes would gain its yield. Several studies that focus on biogas production are reviewed which supports for further researches to be carried out. It concludes that biogas production from animal and household litter, agriculture remains, organic residues, etc. would be an adoptable technique in providing stable source of bioenergy especially for energy starved developing nations.

2. BIOMETHANATION

[3] evaluated biogas generation from dairy manure and food waste and then compared with the quantity obtained from manure and food waste separately. Dairy manure and food waste were collected from different locations and processed and then subjected to fine and coarse fraction. It was co-digested using anaerobic digesters at mesophilic condition for 30 days and finally mixed with bacterial culture. It is said that the water level added to the substrate must be accurate since it determines the total solids apart from its influence over digester size, digestate and treatment cost. Besides the production of biogas, the by-product, digestate favor plant growth due to the conversion of organic matter to inorganic form. Figure 2 shows the biogas yield at different ratio of substrate used.

It is proved that results from the mixture of these two enhanced biogas yield

after digesting them for more than two weeks. [4] Anaerobic disintegration was conducted in four reactors with different waste ratio. CHN analyzer was used to determine the carbon and nitrogen matter of poultry and cow manure, which includes Orsat gas analyzer and water displacement system to evaluate gas composition and production accordingly. Since the carbon to nitrogen ratio of poultry waste is just 7.5, it is not high enough to generate biogas and so adding cow manure increases C/N ratio. Besides, cow manure is rich in microbes that promote for anaerobic disintegration. In this, poultry (75%) and cow (25%) manure were found to be effective for volatile solids minimization of 52% and optimum methane production of 73%.



Adapted from [3]

Figure 2. Biogas yield at different proportions

[5] Waste activated sludge has been bacterially pretreated using surfactant dioctyl sodium sulphosuccinate thus enhancing its biodegradation. COD (chemical O₂ demand) solubilization enhancement of deflocculated sludge has been found to be 6% than from the sludge without subjected to EPS removal. This approach is economically profitable where a net profit of about 57\$ is obtained per unit ton of sludge. [6] Ethylene diamine tetra acetic acid has been used to remove EPS when treated with bacterial medium that enhanced aerobic digestion [7] Activated carbon enhanced disintegration of poultry blood thereby further improving biogas yield. It was determined that CO₂ rich micro-bubble accelerated biogas generation, where the addition of lower amount of pure nitrogen affect methane yield, whereas sparging CO₂ raised its yield. Biogas recirculation increases

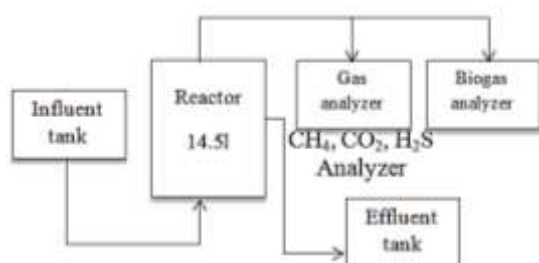
methane generation up to 15%. [8] presented a concept of improving anaerobic wastewater treatments where effluents of sugar and bioelectric plant have been used to produce biofuel and their parameters are shown in table 1.

Adapted from [8]

Table 1.Attributes of sugar and bioelectric plant effluent

Factors	Properties
COD loading rate	140 kg COD/d
pH	6.5-8.5
Temperature	29-41°C
Total suspended solids	150 mg/L
Volatile fatty acid	1000-1500 mg/L

It is efficient in removing volatile fatty acids at around 40°C. Methane yield was found to be optimum at 40°C and beyond this, the yield tends to be degrading. Up flow anaerobic sludge blanket as given in figure 3 is used in this process that decreases LPG cost factors.



Adapted from [8]

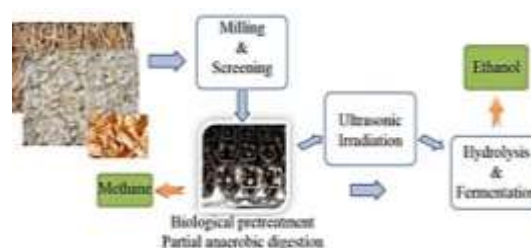
Figure 3.Upflow anaerobic sludge blanket reactor

The procedure took place in three phases as

- 3-16 days at <35°C; methane quantity: 0.30 m³ CH₄/kg_{COD}
- 16-28 days at around 39°C; methane quantity: 0.37 m³ CH₄/kg_{COD}
- 28-35 days at 41°C; methane quantity: 0.22 m³ CH₄/kg_{COD}

[9] Accumulation of algae leads to eutrophication and that can be collected and used for biofuel production. As an account of these, different types of algae were used to produce biogas where methane quantity in total biogas was found to be 52%. [10] conducted experiments on the biogas production from the effluents of palm oil mill plant mainly focusing on empty fruit bunches (rich in total solids, cellulose and carbohydrate), fibrous residue (remains of oil extraction) and decanter cake (contains more hemicellulose other than total solids). Among these, empty fruit bunches yielded maximum methane while decanter

cake produced the least yield. The total methane quantity and biodegradability were found to be 2200 ml CH₄/gVS and 90% approximately. Similarly palm oil frond results in bioethanol by saccharification and fermentation, whereas refined palm oil leads to biodiesel yield. It can also yield ethanol using biocatalyst. Experimental analysis in micro reactor reveals that production of fatty acid ethyl ester and biodiesel at around 350°C is better and their yields are observed by 67% and 78% respectively. It is also noted that higher temperature ends in lower production due to thermal decomposition. [11] Comparing to other greeneries, grass yields minimal quantity of biogas due to its lignocellulose complexity. So in this regard, multi pretreatment methods have to be done in order to increase its quantity. Lignocellulose like bagasse results in bio oil when it undergoes microwave pyrolysis. [12] An another example of lignocellulose is straw, where the conversion of straw to ethyl alcohol is complicated since it contains large quantity of ash and silica. By selecting proper pretreatment methods, the challenges in biofuel production from lignocellulosic substrates can be met. [13] Even anaerobic pretreatment with ultra-sonication increased ethanol production for lignocellulose. In this context, rice hay, sycamore and pine were used which were hydrolyzed and fermented. Rice residues yielded maximum biogas out of these three, with ethanol content of 70%. Figure 4 depicts the combined system of biological pretreatment with ultra-sonication.

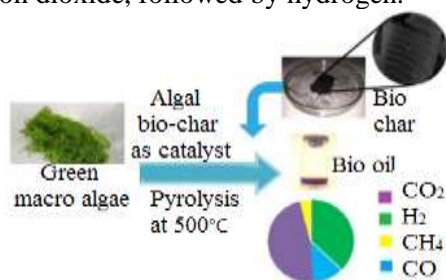


Adapted from [13]

Figure 4.Combination of biological pretreatment and ultra-sonication

[14] Corn residues are also proved to be effective renewable energy source. This method focused on supply chain analysis and promotion of energy generation from biomass. When tomato remains (13%) was anaerobically co-digested with dairy waste (54%) and corn stover (33%) at 20% total

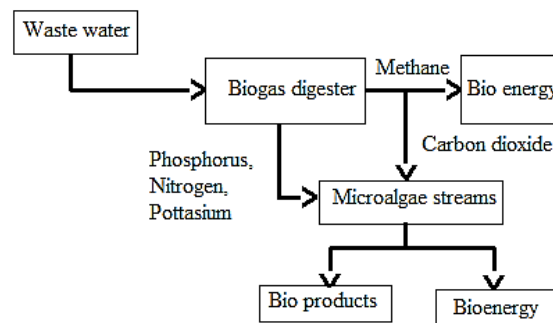
solids, volatile solid degradation and CH₄ production were observed by 46% and 145 l, however >40% tomato waste resulted in extreme generation of volatile fatty acids, thus inhibiting fuel yield. [15] reports that even indigestible substrates can be converted to biogas through fermentation. Such cases may or may not include pretreatments. Some of the common methods preferred could be physical/ acid/ alkali/ biological pretreatments or decompression or hydrolysis. [16] Cyanide containing tapioca was co digested with pig manure. The substrate with 35:1 carbon to nitrogen ratio was used. Initially 1 kgVS/m³d loading is maintained in the reactor for about two months. In this, additional loading of 6 kgVS/m³d increases the performance stability where the volatile solid reduction and methane production were found to be 80% and 0.4m³/kg accordingly. Degradation of cyanide from tapioca was practicable and anaerobic disintegration of cassava pulp and pig waste was done without any negative impact of cyanide. [17] Macro algae produce biofuel through pyrolysis. Bio oil yield was checked at various temperatures, where catalytic test reveals that maximum content was recovered at 500°C. Its graphical abstract was given in figure 5. The major portion of the product was carbon dioxide, followed by hydrogen.



Adapted from [17]

Figure 5. Bio oil generation from green algae

Apart from pyrolysis, hydrothermal hydrolysis could be also included to produce bio oil. The quality of bio oil must be improved from its high oxygen and acidity content. [18] Microalgae yield biofuel in addition to valuable releases like proteins and antioxidants. In this regard, as wastewater area itself acts as growth substrate, development cost can be reduced. It focused on the conversion of palm mill oil effluent, where microalgae grow, (rich in chemical oxygen demand value) to biofuel. Figure 6 illustrates the integration of micro algae-biogas system.



Adapted from [18]

Figure 6. Integrated biofuel-microalgae process

[19] characterized the digestate of co digestion that are obtained from degradation of untreated and thermally pretreated micro algae with and without co-digestion with slurry. The digestate of micro algae treatment contains organic and ammonium nitrogen and that can be reused for agricultural purpose. Co digestion improved dewater-ability and stability. The results show that,

- The digestate that were thermally pretreated was the one with minimal stability.
- Co digestion resulted in slighter phytotoxicity.
- All digestate contained fewer amount of E.coli strains.

Hence the digestate that obtained after thermal pretreatment and co-digestion with sludge was observed to be more effective for agricultural reuse. The experimentation is showcased in figure 7.



Adapted from [19]

Figure 7. Digestate use after pretreated co-digestion

[20] While several articles focused on the production of biogas, bio methanol yield has been dealt using bio reactor. Solid waste from fruit and vegetable along with goat and poultry manure were used to retrieve bio gas by means of gas and liquid chromatograph. It was observed that after a week of hydraulic retention period, bio methanol yield out of

74% methane is 2.5% at 33°C. It states that goat manure suits more for the maximum generation of bio methanol. [21] Hydraulic retention period, organic loading speed and rate of degradation are the factors that affect specific CH₄ potential and methane yield. Further, the types and quantity of co-substrates influence the total fuel yield, specific methane potential and digestate composites. For these things, the operation and effectiveness of reactors are vital. [22] With an intention to generate energy, water hyacinth and sheep waste were used employing alkali pretreatment. The mixture was anaerobically co-digested at mesophilic condition for about two months.



Adapted from [22]

Figure 8. Biomethanation unit

Figure 8 represents the biomethanation unit consisting of thermo bath, bio-digester and gas collectors. The pH and total and volatile solids of sheep waste are given by 6.7, 33% and 74% and for water hyacinth they are 6.4, 17% and 83% respectively. The collected water hyacinth was treated with 1% of sodium hydroxide for 48 hours. The NaOH was removed and the remains were dried initially by sunlight and then by oven at 60°C for 6 h which was then powdered and mixed with sheep waste. The feedstock of sheep waste in the digester started yielding biogas from day 5 onwards, whereas water hyacinth yielded after 10 days, thus proving that alkali pretreated weed when co-digested with sheep waste results in optimum biofuel yield. At 4 (hyacinth): 12 (sheep waste) :84 (water) proportion, maximum biogas production has been obtained with 61% of methane, 22% of carbon dioxide and remaining percentage of other gases like hydrogen, nitrogen and hydrogen sulfide and moisture. [23] By taking household organic and cow waste into

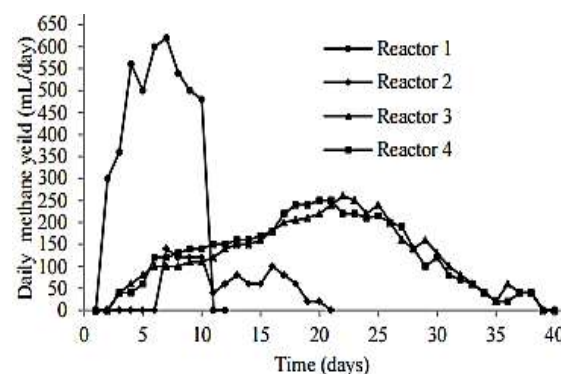
analysis, optimum CH₄ yield of 247 ml/g was produced. Both cow manure and household waste were collected and maintained at 4°C until they are pretreated. By then inoculum was prepared, where the characteristics of substrate and inoculum are defined in table 2.

Adapted from [23]

Table 2. Composition of feedstock and inoculum

Parameter	Household waste	Cow manure	Inoculum
pH	5.3	7.5	8.3
Total solids	40	15	26
Volatile solids	30	14	22
Moisture	11	11	25
Ammonia	4.3	27	15

Four set of experiments were carried out in reactors namely R₁, R₂, R₃ and R₄. In household and cow waste, the total solids are of 15% and 5% accordingly. In reactor R₁, only cow manure of 760 ml was utilized, whereas in R₂, 760 ml household organic waste was used. In R₃, both the substrates are employed with 380 ml each and the reactor R₄ includes 506 ml household waste and 254 ml cow manure. In all these, 40 ml of inoculum was maintained. From these batch experiments it is clear that maximum production was from reactor R₃ followed by R₄ (243 ml/g). Methane production on daily basis is represented in figure 9.



Adapted from [23]

Figure 9. CH₄ yield of high solid anaerobic codigestion

[24] Trash from kitchen is rich in calories and nutrition and that can be biodegradable to a greater extent, thereby the requirement of fossil fuels can be lowered. Here the cookery waste has been combined with that of cow manure and is anaerobically disintegrated. The domestic garbage used for

analysis contained 70% of rotten rice and veggies. At first, three digesters with household waste, cow manure and then both combined were constructed at normal and mesophilic condition. Results show that the disintegration rate of the third digester was better than the first two. Thereafter the alkaline impact at 37°C was assessed using three sets of NaOH dosage of 1%, 1.5% and 2%, from where the second option was considered to be optimum. Hence the defragmentation rate was found to be 6.8 ml/gm at 200 gm/l loading rate. This project also included a movable biogas reactor and it was determined that the degradation rate was higher at 37°C than ambient temperature. [25] Vegetable (78%), fruit (18%) and tuber (4%) wastes accounting to a total of 160 kg yielded 65% CH₄ with biogas formation of around 40 ml/ min at normal temperature. The feedstock was manually mixed and the feeding took place for 14 days inn which the moisture in the waste was determined as 47.7%. Total nitrogen, organic carbon and phosphorus were found to be 0.6%, 22% and 523 m/kg correspondingly. They are of 4418 cal/g (calories), and its C/N ratio and total solids were given by 38% and 10% respectively. Since its moisture content is high, this cannot be incinerated or landfilled and so the only way to convert this to biofuel is anaerobic digestion. The resultant was 50-70% of CH₄, 30-45% of CO₂ and <4000 ppm of H₂S. [26] dealt with waste activated sludge and cattle manure which was cooled at 4°C until it was processed. Once the inoculum was ready, the slurry was fed to the digester and incubated at 55°C. The total biogas yield (M) was calculated using modified Gompertz equation as in ,

$$M = P. \exp \left\{ -\exp \left[\frac{R_{m,e}}{P} (\lambda - t) + 1 \right] \right\} \quad (2.1)$$

where P refers to biogas yield potential, R_m denotes the optimum generation rate/day, λ and t corresponds to duration of the lag phase and the assay accordingly. All these elements were assessed by means of POLYMATH and MATLAB. The characteristics of biomass used in this study in provided in table 3.

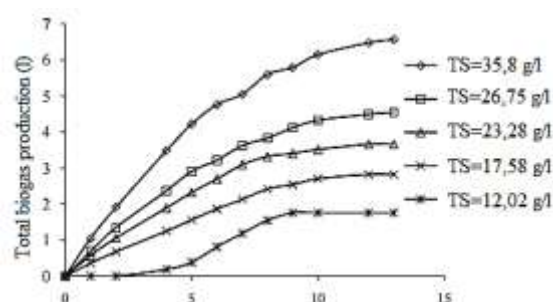
The results as shown in figure 10, prove that as total solids increase, total biogas level also goes higher. Like wise relative methane production also increased with

increase in total solids and at 35.8 g/l, maximum CH₄ was obtained.

Adapted from [26]

Table 3.Composition of the sludge used

Materials	Activated sludge	Cattle manure
Total solids (g/l)	24	54
Volatile (g/l)	11	29
Chemical O ₂ demand (mg/l)	780	18720
Ammonium (mg/l)	19	720
Nitrate (mg/l)	4	78
Phosphate(mg/l)	42	7
pH	7	7
Moisture (%)	98	46



Adapted from [26]

Figure 10.Biogas yield vs total solids

Fuels from biomass is given importance as of that solar energy as both are renewable and recoverable [27]. Electricity generation from marine algal breakdown shows positive effects, where it influences solid substrate loading, anaerobic degradation and retention time. [28] Investigation was made with respect to the anaerobic degradation of canned seafood and glycerol residues. The optimal condition for the CH₄ generation was observed by 570 ml/g using seafood and glycerol waste at ratio 99:1. Meanwhile 58 kWh electricity has been generated from 1 m³ wastewater. Sludge blanket reactors produced 2.3 lCH₄/d. COD and biodegradability optimization has also been achieved while adding 1% glycerol to 99% of canned seafood wastewater. [29] utilized chicken processing waste and silver and sea grass as co-feedstocks for the production of CH₄ using chicken waste. In this attempt, first order and modified Gompertz relation have been employed to analyze the reactions involved in digestion. No substrate remained unchanged to methane. The co-digestion of sea and silver grass influenced

for high CH₄ quantity, among the three co-substrates used, sea grass showed considerable synergistic effects. The experimental results of co-digestion were observed to be around 35% higher than the results obtained from biochemical methane potential of mono digestion. [30] related that biological co-pretreatment could enhance hydrolysis and acidogenesis of slurry thus in turn improving anaerobic co-digestion. An increase of 25% and 10% has been noted in reference with methane quantity and solid degradation when compared to sludge decomposition without pretreatment. The process has been compared with that of mono digestion also, where co-digestion results were more positive, owing to impacts of pH changes and solubilization of waste activated sludge. Furthermore it was also noted that the growth of bacterial species, *Levilinea* could be limited that often caused negative effects during defragmentation. [31] Anaerobic co-degradation of food litter and sewage sludge in 2-phase mesophilic reactors was conducted where 20% enhancement of methane gas was achieved in comparison with mono digestion. The used bio reactors are acidogenic and methanogenic that are simultaneously exercised and the feedstocks are mono and co digested. The reason behind this increased results of co digestion is due to the proper setting of C/N ratio. It is deduced that 2-phase digester mode is preferred to single phased operation as its buffering capacity is higher. This work suggests that both co-digestion and two phased reactor system would be beneficial in promoting sustainable methane yield. [32] analyzed the feasibility of anaerobic degradation of spent coffee grounds co digested with other organic waste. The resultant was assessed corresponding to different substrate proportion using batch biochemical CH₄ experiments. In this attempt, when waste activated sludge was co-digested with coffee grounds, the rate of methane was tend to be degraded, whereas other organic co-effluents raised its yield. The digestion rate enhanced with the increase in contents of co-waste without causing any loss in generation potential.

3. INFLUENCE OF TOTAL SOLID CONCENTRATION

[33] When sugar beet was co digested with cattle manures with 8% and 5% of total solids, the former with higher concentration

exhibited effective results with specific CH₄ production of 464 ml/g. But above 8%, its rheological characteristics were not better and so it was not studied. Accumulation of huge quantity of volatile fatty acids delayed the process but in reduction of organic matter, both the results of solid concentration were same. [34] reiterated that total solids quantity of 25% exhibited greater utility of water soluble carbohydrate than with >30% of total solids, where the lactic acid yield is also high, but the latter is found to be good for sugar production. The results validate higher CH₄ yield at 40% total solids, while 25% total solids resulted in lower glucose and methane generation. [35] stated that volumetric biogas emission increases with increase in total solids, even though its quantity per gram volatile solids reduced. Increase in total solids caused rise in solids that were resulted by centrifugation of sludge at 2000g for few minutes. It is therefore concluded that higher portion of total solid mixture with dewatered slurry ends up in obtaining high degradable loading rate and methane production, i.e. optimizing total solids leads to higher volumetric biofuel generation rate and dewatering effects. [36] presented the effects of total solids over thickened waste disintegration. In this experimental analysis, 50 l reactor functioned in semi-continuous mode was fed with the remains of municipal solid garbage. Steady state analysis prove that around 28% of total solids was ideal for volumetric biological actions.

4. MATHEMATICAL AND NEURAL MODELLING

Anaerobic disintegration manages waste disposal and energy crisis by converting waste to energy rich fuel primarily made of CO₂ and CH₄. It is important to minimize plant development cost and optimize operation. Mathematical modeling is helpful in dealing with this, which includes physico-chemical reaction, thereby the factors that affect fuel yield can be analyzed. Simplex-centroid and regression function can be adopted in multi objective optimization methods to quantify CH₄ production. Applications of control theory models become prioritized in optimization of fermentation task and in resolving certain issues in production of renewable bioenergy from food waste and sewage sludge. Bio-kinetic modeling could be included in microbial action, feedstock breakdown and

biogas yield. In general, modeling on the basis of biomass balance is done which is simulated using MATLAB by altering the initial concentration and dosage of organic matter. Once biogas is generated from waste sludge, it is purified to get rid of H_2O , H_2S , CO_2 , NH_3 , etc. It is then generally subjected to Brayton cycle and nonlinear strategies to generate energy at optimal condition. [37] Since anaerobic digestion is complex, modeling like state-of-art aims to optimize and estimate the operational efficiency of reactors that simulates biogas production and digester stabilization. It also describes feedstock composition, rate constraint factors, function inhibition and generation rate. Apart from these, it relates the usage of operational fluid dynamics. [38] The problems of sledge fermentation can be overcome by black box approach of neural analysis. This structural model was employed in estimating CH_4 emission during livestock waste fermentation. It aids in performing comprehensive description of the arising complexities like predicting biogas production by sledge processing. [39] described the efficiency of bio reactor in determining pH, volatile solids and fatty acids and methane content during biogas emission from anaerobic degradation of organic waste loaded at $<120 \text{ kg volatile solids/m}^3$. The organic municipal garbage yielded 347 l methane in where the outcomes were statistically optimized using artificial neural model. [40] Biofuel production is said to be optimized only if it undergoes proper kinetic estimation. The kinetic attributes of co-digestion are forecasted by regression based models employing ratios of co-effluents where the kinetic characteristics for single feedstock were regarded as indicators. The rate of hydrolysis and methanogenesis was determined by these models by applying them to the improved first order kinetics and Monod structure. In this, hyperbolic and inverse tangent parameters were found to be effective in estimating first order kinetics and Monod model respectively and they are well suited for micro algae/swine waste /waste activated sludge/seaweed conversion. First order kinetics can be merged to numerical system to achieve high precision modeling of fuel yield. It is recommended that identifying initial quantity of volatile fatty acids is helpful in enhancing stability between model and experimental values. [41] A Particle Swarm Optimization

(PSO) technique has been used to calibrate all characteristics such that the complexities of tuning anaerobic degradation system could be reduced. In relation with this, a digester was supplied with glucose until reaching steady state in which both the steady and transient states of the reactor was provided to the smart PSO algorithm. As a result, around 14 characteristics are predicted, of which 10 resembled so close to the experimental data, thereby the model is validated. [42] Using multi-layer neural and PSO model, optimization of CH_4 and biogas with 1-output and optimization of biogas quality (CH_4 , CO_2 , etc) and yield with 2-outputs were structured. Ideal input and output values are obtained with respect to the structured models and values from wastewater processing that is expected to enhance biofuel quantity and quality-wise. [43] Modified sigmoidal bacterial growth curve relations using nonlinear least square regression assessment were employed to kinetically evaluate CH_4 production. Though this method comprising Richards, logistics, Gompertz model is suitable in case with high fatty waste digestion, it becomes complex in solving inflection points and in such case, this model is further extended. [44] Mathematical modeling using MATLAB Simulink of paint residual has been described focusing on bio chemical O_2 demand and total solids. [45] Such models also assist in evaluating biotechnological operation of CH_4 yield from anaerobic breakdown. The proposed method has been conducted in two connected digesters, where the model includes equilibrium point calculations and their stableness in relation with input/output parameters. Additionally, web based numerical computation in demonstrating the dynamic characteristics of the model have been described. Practical implementations are allowed to be carried out by considering all the facts thereby bioreactors could be optimized to produce maximum fuel yield.

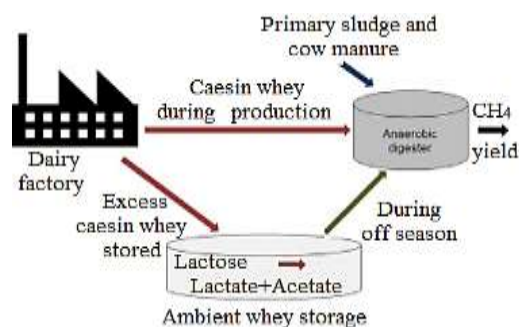
5. CHALLENGES IN BIOMETHANE YIELD

[46] elaborated the challenges of anaerobic digestion. Plants get combusted to bio-char that can improve anaerobic disintegration and its resultant, digestate enhances soil ecosystem. Therefore degradation process must be stabilized and pave way for the cultivation of nutrient

retention ability in order to achieve these benefits. In this circumstance, substrate/feedstock induced inhibition has to be considered that disrupts the stabilization affecting microbial conversion of sludge to CH_4 or biogas. Similarly improper digestate management might lead to surface runoff and loss. Micro algae digestion for biogas generation poses threat if carbon to nitrogen ratio is lower. [47] For instance, use of *Arthrospira platensis* might lead to NH_3 inhibition and reduces degradation stability. In such case, it can be fermented with carbon rich co-feed-stocks like barley/wheat straw at carbon to nitrogen proportion of 25 so that the co-digestion is further improved. Even though the batch fermentation results were not productive enough in confirming synergistic impacts, the operation stability was enhanced. For the same micro algae, it was found to be stable only at 1 l/d when it was mono digested, but when it is co-digested with seaweed, optimal biomass conversion was achieved. The process was stable at 4 g/l/d loading. [48] During anaerobic digestion, temperature, pH and acidity/alkalinity are the factors that influence the disintegration. Further, external parameters like magnitude, time period and frequency affect the reactors in turn to efficiency degradation, volatile fatty acids collection at large scale and pH decline. By proper removal of carbon dioxide, hydrogen sulfide, surplus water content and trace gases, biofuel formation can be upgraded. [49] addressed that the seasonality of whey yield, getting delayed in starting-up and utilizing huge quantity of manure are the risk factors in enabling full scale usage of casein whey. Comparison analysis reveals that whey when digested with any manure upgrades biofuel yield by 80% than when digested with primary slurry alone. It is suggested that the storage time of whey should not be extended for longer days for optimal methane production. Substrate loading of slurry: whey: cow manure of 10:5:1 and 10:7:1 for fresh and stored whey was favored for ideal results correspondingly. The pictorial representation of biogas yield from whey, primary sludge and manure is represented in figure 11.

Thus the review concentrates on certain waste products and manures that yield biofuel and by products that are beneficial for economy and soil conservation. Mathematical

and kinetic models add benefits to the ideal methane and biogas emission.



Adapted from [49]

Figure 11. Methane production from stored whey

6. CONCLUSION AND RECOMMENDATION

Due to the spectacular usage of bioreactors intending to biogas yield via anaerobic digestion, the exact energy as produced from fossil energy sources are obtained by reducing exhausts. It is therefore essential to deal with all the constraints of reactors that degrade biogas production. Most of the referred articles demonstrate that anaerobic co digestion is the most appropriate technology for bioenergy generation and its digestate are more nutritive for agricultural usage. Apart from managing supply chain, drying, grinding and other processing of substrates are vital to enhance their properties used for fuel production. All sorts of agriculture, industrial and household remains could be pretreated and anaerobically digested to promote renewable, clean and sustainable bioenergy. Reactor and temperature control factors are essential to get enhanced as bioenergy from anaerobic co-digestion seems to be an effective approach for many feed-stocks to get transformed to valuable products.

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